Food Webs

• Basics
  – Food Chain – the transfer of energy through a series of organisms
    As energy is passed through these chains much of it is lost as heat (80 –90%)
  – Two Kinds of Food Chains
    • Grazing – begin with autotrophs → herbivores → carnivores
    • Detritus – begin with nonliving organic material → microorganisms
  – Food Web – the interconnecting of food chains
  – Trophic Levels
    • 1\textsuperscript{st} trophic level – green plants
    • 2\textsuperscript{nd} trophic level – herbivores
    • 3\textsuperscript{rd} trophic level – carnivores (both primary and secondary)
Food Webs

Simplified Food Chain

North American Tundra

Plants
*Cladonia* (reindeer moss), grasses, sedges, dwarf willows

Herbivores

Caribou

Lemming, Arctic Grouse

Carnivores

Wolf and man

Arctic Fox, Snowy Owl, other raptors
Food Webs

The Antarctic pelagic food web.

- Killer whale
- Leopard seal
- Ross seal
- Weddell seal
- Larger fish
- Blue whale
- Crabeater seal
- Flying birds
- Adele penguin
- Small fish and squid
- Skua
- Emperor penguin
- Krill
- Diatoms
Simple food web of an Arctic island.
Food Webs

- Weinmuller (1990) – studied food webs in the tropics – he selected a system where there was only 10 fish and found the web to be extremely complex.

Even a food web with only 10 fish species and their foods can be very complex.

However, removing weak feeding relationships produces a more understandable picture of the community.

Food web representing the feeding relations of the 10 most common fish species at Caño Volcán, Venezuela.
Food Webs

• Strong Interactions in Food Webs
  
  – Paine (1980) – come up with the idea of *strong interactions* (some species have a much greater effect on community structure than others)
  
  – Tscharntke (1992) – studied a food web that centered around *Phragmites*
Food Webs

By studying such interactions, *keystone species*, were identified (those that have a substantial influence on community structure)

Paine’s ideas on keystone species came from the following reasoning:

- Predators keep prey below their carrying capacity
- Competitive exclusion would be low if organisms are kept below their carrying capacity
- In the absence of competitive exclusion species diversity would increase
Food Webs

- Food Web Structure and Species Diversity

  - Paine looked at proportion of predators in a food web and the relationship to diversity – found that in looking at zooplankton as diversity went up % predators also increased
Food Webs

- Experimental Evidence

- Paine removed the predator from the first food web (starfish) over a two year study
  - In the experimental plots the number of species dropped from 15 to 8
  - Showed that the starfish function as a keystone species
  - In the absence of the starfish competition between the remaining species resulted in their reduction

- Paine demonstrated the same results in a different intertidal environment thousands of kilometers from the first
Food Webs

• Consumer Effects on Local Diversity
  – Jane Lubchenko (1978) – studied the fact that sometimes herbivores increase biodiversity while other times they decrease it, and sometimes both – to study this she looked at:
    • Food preferences of herbivores
    • Competition between plant species
    • How feeding preferences and competition varied across environments

She studied the snails *Littorina* and the algae they feed on in intertidal pools and found
  – A preference for a delicate ephemeral species, *Enteromorpha* and disliked the perennial which was tough, *Chondus*
  – Pools with high *Enteromorpha* had low density of snails
  – Pools with high *Littorina* had high amounts of *Chondus*

She proposed that without *Littorina* competition from *Enteromorpha* excluded *Chondus* - To test this she removed the snails from a pool where they were high and placed them in pools where *Enteromorpha* was dominant
Feeding by the intertidal snail *Littorina* affects the composition of algal communities in tide pools.

Without manipulation of *Littorina* the abundances of dominant algae remained relatively constant.

Adding *Littorina* to a tide pool that had few of the snails reduced *Enteromorpha* cover.

Removing *Littorina* from a tide pool where it had been abundant increased *Enteromorpha* cover.

Effect of *Littorina littorea* on algal communities in tide pools.
Effect of *Littorina littorea* on algal species richness in tide pools and emergent habitats.

**In tide pools algal species richness was highest at intermediate densities of *Littorina*.**

**On emergent habitats, algal richness was highest where *Littorina* densities were low.**

- **Reasons for what we see in left graph:**
  - With low density the ephemeral species dominates
  - At moderate densities *Littorina* keeps the algae numbers low preventing competitive exclusion
  - At high densities snails will eat anything and reduce all diversity

- **Reasons for right graph:**
  - Both snails and aggressive distasteful algae are competing against the more delicate and tasteful algae
Fish as Keystone Species in River Food Webs

Mary Power (1990) – looked at the Eel River in Northern California –

Food web associated with algal turf during the summer in the Eel River, California.
Food Webs

She performed an experiment where she excluded large fish from some areas and permitted them to exist in others.

Enclosing fish over an area of streambed significantly reduced algal biomass.

The influence of juvenile steelhead and California roach on benthic algal biomass in the Eel River.

Effect of juvenile steelhead and roach on numbers of insects and young (fry) roach and sticklebacks.
Food Webs

- Effects in Terrestrial Systems – Predation by Birds on Herbivory

  - Altegrim (1989) studied boreal forests in Northern Sweden, studying the affects of birds eating herbivores and in turn their affect on the vegetation – posed three questions:

    - Do birds reduce the density of insect larvae feeding on *Vaccinium*?

    - Do birds have different effects on larvae feeding from exposed versus concealed positions?

    - Does predation by birds reduce larval insect damage to the shoots of *Vaccinium*?

He designed an experiment where he excluded birds from feeding on *Vaccinium* and made sure that no other effects resulted from the enclosures.
In answer to his other two questions he found that yes insect exposure did affect predation and that yes, increased insect densities did affect growth of *Vaccinium* shoots in a negative way.
Food Webs

- Marquis and Whelan (1994) looked not only at the affect of birds on insectivorous herbivores but also their affects on biomass production.

Effect of insectivorous birds on herbivorous insect populations, leaf damage, and sapling growth in white oaks.
Characteristics of a Keystone Species

- Species with low biomass but large effects on community structure.
- Keystone species are those whose influence on a community is disproportionate to their biomass.
- Dominant species are ones that have significant influence on community structures by virtue of high biomass.
Food Webs

Influence of an exotic predator, Nile perch, on the food web of Lake Victoria.

Simplified version of original food web

Piscivorous catfish and cichlids

Insectivores

Before the introduction of Nile perch, the food web of Lake Victoria included more than 400 species.

Introduction of Nile perch

Altered food web

Large Nile perch

Now the food web and fish catches are dominated by just three species.
Mutualistic Keystones

- Cleaner Fish as Keystone Species
  - On coral reefs some fish clean other fish of ectoparasites
    - Cleaner wrasse, *Lambroides dimiditatus*, can eat 1,200 ectoparasites/day
  - Effects of removal and addition experiments

![Graph showing the impact of adding or removing cleaner wrasses on fish species richness](image)
Mutualistic Keystones

• Seed Dispersal Mutualists as Keystone Species
  
  – Christian (2001) found that ants disperse 30% of seeds in some South African shrublands

  • Ants attracted to plants by eliasomes
  
  • Recent invasion by an Argentine ant that do not disperse seeds
Mutualistic Keystones

- Seed dispersing ants bury seeds protecting them from fire (which are common in these areas of South Africa) and grainivores
- Seed dispersing ants effect mostly large-seeded plants
- Effects

Recruitment of seedlings by large-seeded plants is strongly suppressed following fires in areas invaded by Argentine ants.